The Rotating Compass: A Novel Interaction Technique for Mobile Navigation

Enrico Rukzio[1], Albrecht Schmidt[2], Antonio Krüger[3]
[1] Media Informatics Group, [2]Embedded Interaction Research Group, University of Munich
{Enrico.Rukzio, Albrecht.Schmidt}@ifi.lmu.de
[3]Institute for Geoinformatics, University of Münster
Antonio.Krueger@uni-muenster.de

ABSTRACT
In current mobile navigation systems users receive the navigational instructions on a visual display or by descriptive audio. The mapping between the provided navigation information and the surrounding world has still to be performed by the users. In our approach that aims at public spaces, we combine a public display that shows directions with a synchronized output on a personal device. We describe a system where on the public display a compass with a rotating needle is shown. When the compass needle points in the desired direction, the mobile device of the user vibrates. This unobtrusive cue, allows the user to navigate without listening to or looking at the mobile device. In this paper we introduce the concept of synchronized information displays for navigation. We describe our prototype of such a system and report on a user study, that shows the feasibility of the approach.

Author Keywords
Personal navigation, mobile interaction, public display, tactile feedback.

ACM Classification Keywords
H.5.2 [Interfaces and Presentation**]:** User Interfaces — Interaction styles; I.3.6 [Computer Graphics]: Methodology and Techniques — Interaction techniques

SYNCHRONIZED INFORMATION DISPLAYS
Navigation systems have seen significant advancements in recent years. They are commonly used in planes, cars, and trucks. Additionally, a variety of mobile devices for pedestrian navigation, for use in urban areas as well as for the wilderness, are commercially available.

We introduce the concept of synchronized displays for providing navigational information. The basic idea is that displays in the environment and a personal device are used in combination. The output of the mobile device is synchronized with an environmental display in the vicinity of the user to provide personalized information.

Our main idea is to enhance the presentations of static directional signs by an animated public display. In our current implementation we visualize a rotating compass needle. The right direction for an individual user is identified through the vibration alarm of the personal device, which is activated whenever the needle points in the right direction. This allows users to identify the relevant direction without a personalised presentation on the public display. In fact the personalisation is achieved through the combination of the public and the personal device. If the mobile device is carried in the pocket, notifications can be delivered absolutely unnoticed by other parties.

The following example illustrates the concept. A user is carrying a mobile device that can vibrate in a pocket. The user approaches a place where she or he can turn right, turn left, go straight ahead, or do a U-turn. At such a decision point a public display (e.g. a projection on the floor) highlights each direction for a few seconds. When all directions have been highlighted clockwise it begins again. The user approaches the decision point and the device she or he carries vibrates always when the way is highlighted that the user should take. An example showing two people approaching a crossing is illustrated in figure 1.

Public Display
The public display is independent of the users that are around. The display highlights different information, such as directions, over time. We call each piece of information

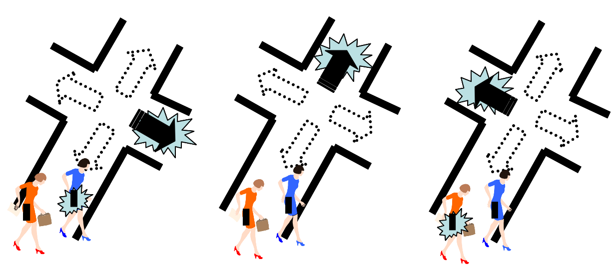

Figure 1. When the public display highlights the direction that a person needs to go the personal device of this person will vibrate. The right person in the blue dress needs to go right (first picture); the left person in the red dress needs to go left (last picture). The display highlights the directions independent of the people around (middle picture).

an *option*. At one point in time one option is highlighted or displayed. Once all options have been highlighted or displayed it starts again. We call the time needed to show all pieces of information once *cycle-time*. The cycle-time is the upper bound of the waiting time for someone using a public display.

The public display can be a projection as sketched in figure 1, where an arrow that changes direction is projected onto the floor. Each direction is one option. Instead of arrows, adverts and logos could be projected as already common in some shopping malls. The pubic display could also be a screen that provides textual information (e.g. “go left”, “go right”, “straight on”), or a simple spot light that highlights signs that are already used in a certain environment. When designing the public display it is important to make it fit the environment where it is placed in. Criteria for such a public display are similar to those for setting up conventional signs. It should be easy for the user to look at the display in the environment while walking. An important design feature is the *distance* at which the user can see the entire display and at which the user is able to discriminate all options displayed. In one location that we investigate (at an airport, 4 projected arrows on the floor, each arrow is 3 meters long) the distance is about 15 meters (under the assumption that people are walking in the area but the area is not over crowded).

The information shown on the public display is on its own – without a personal device – not useful for navigation. And hence the information displayed does not reveal personal information. To make it usable with a personal mobile device, it is important that the timing of the public display is known. I.e. it must be known when a certain option is highlighted, e.g. when the arrow pointing left in figure 1 is highlighted. This information must be available to the mobile device to allow synchronized notification.

Personal Device

The function of the personal device is to give the user the notification that the currently displayed option on the public display is targeted at her or him. To do this the output of the personal device is synchronized with the public display.

The display on the personal device can have a minimal communication bandwidth to the user. A binary display is in general enough as the function of the personal display is to make the user aware that the currently displayed public information is for her or him. Examples of such displays are a vibration motor (as in a mobile phone), a single LED integrated in a watch or into glasses, or a sound signal. Such a sound signal could be mixed in with the music a user is listening to. In such a scenario a personal stereo worn by the user could be used as an output device (e.g. headphones of a mobile mp3-player).

Personal displays that only communicate one bit can be designed very unobtrusively. The vibrations of a device or the additional sound on the personal stereo are only recognizable by the user and not by others.

In the cases we investigated, the time constraints for the synchronization are in the order of several hundred milliseconds. This makes it possible to work with clocks on both devices and does not necessarily require a wireless connection for synchronization. It is however necessary that the personal device knows when it approaches a decision point. As the accuracy required is only at which crossing the user currently is, this can be realized by a simple and coarse location system, e.g. based on radio beacons.

Navigation System

A synchronized navigation system consists of a personal device for each user and a public display at each decision point in the navigation space. Additionally, a system component providing location information is required.

For implementing the navigation there are two basic options. At each public display the personal device must be able to retrieve the current location or the personal device must tell where it wants to go. In the first approach the route is held on the personal device and the environment is not informed where the user is going. The environment tells the personal device where the user currently is and what options are available. Based on this information and the known target, the option that is right for the user is chosen. In the second approach the user asks at each decision point the environment where she or he should go telling the system the final target. The system tells then the mobile device which option is right. The first approach has obviously the advantage that the user’s privacy is preserved whereas the second one is simpler to implement for the mobile device as no advanced logic is required for this device.

To design a navigation system where people do not have to stop, we provide the following estimates. We assume a walking speed of 1.5m/sec and that the change of direction is directly at the public display. To allow users to retrieve the relevant navigation cue without the need to stop it is required that *cycle-time* is less or equal to the *distance*/1.5.

PROTOTYPE OF THE NAVIGATION SYSTEM

We built a prototype of a synchronized navigation system to perform user tests. We wanted to explore if such a navigation system can be understood by users, what the user experience is, and what effect the cycle-time has on the user experience. The prototype consists of a public display that is projected onto the floor and a mobile phone used as a personal device.

The projected display shows a circle with a rotating pointer which looks similar to a compass, see figure 2. The public display is implemented as a web page and the graphics are programmed in SVG. The program can be parameterized to change the number of directions available, the time needed to complete one circle, and the layout of the presentation (e.g. colors, additional lines). We used a ceiling mounted video projector to project the display onto the floor.

A Java application on a mobile phone was developed that allows to switch the vibration motor of the phone on and off. The software is based on J2ME / MIDP 2.0 and we used a Siemens S65 phone. The application is parameterized with the characteristics of the public display that is used (cycle time, number of options, and option names). The application offers two modes. In the predefined mode a list of options and timings is given to the application and the phone 'plays this list' where each option is played twice consecutively. In random mode the phone selects random options, presents them, and waits till the user acknowledges the direction with the keyboard.

For synchronizing the clocks on the phone and in the public display a further application on the phone was developed. Before the experiment the experimenter presses a button when the pointer in the public display is at a certain position. The synchronization has to be performed only once per experiment as the clock drift is minimal.

To provide the phone with the current location a Bluetooth adapter is used with the public display that can be enquired by the phone application. This feature was not used as the user study was performed with a single public display.

STUDY AND PRELIMINARY RESULTS

Using the prototype described in the last section we performed a user study. We had 14 volunteers that participated in our study, 6 women and 8 men, aged from 22 to 44.

Study Setup

We setup the public display as a projection in a large room. The projected display on the floor was approximately 1.5 meters by 1.3 meters. The number of options was 4 and they were orthogonal. It was in the middle of the room so that people could walk around it. The mobile phone and the public display were synchronized before the experiment.

Participant got the following introduction read to them: *"Imagine this installation in a public place in larger size. You have entered your destination in your mobile phone before. Now you come to a point where the system tells you which way to go. Follow in the direction where the arrow is when your phone vibrates."*

The participants were handed the phone and then the following experiments were performed. The order of test 1 and test 2 was alternated between participants.

Test 1: The user holds the phone in her or his hand. Each time it vibrates the users goes to the direction indicated by the public display and acknowledges the step by pressing a button. The same direction is repeated until the user acknowledges. The cycle time in the experiment was 16 seconds, 2 seconds per option and 2 second between options. In total 10 directions where indicated for each user.

Test 2: the same as test 1 except cycle-time is 8 seconds, 1 second per option and 1 second between options.

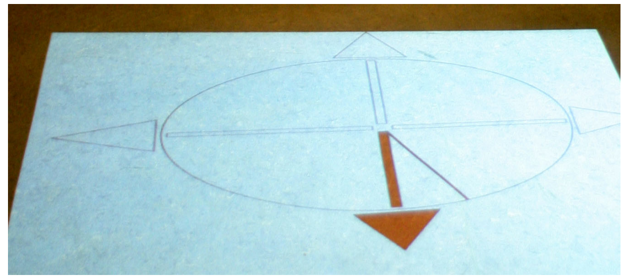

Figure 2. The public display realized as a projection on the floor. It shows the 4 possible directions. The current option is highlighted by a red arrow. A thin line is moving around with constant speed.

Then users where asked if they could describe the difference between test 1 and test 2.

Test 3: users are instructed to put the phone into a pocket in their garment. Then whenever the phone vibrates the user has to go in the indicated direction. Each direction is indicated twice to avoid that the users need to take the phone out of their pockets for confirmation. If the users recognized it the first time they did not move at the second time. In total 20 direction (each 2 times consecutively) were indicated to each user, half of them with a cycle time of 8 seconds and the other half with 16 seconds. After the tests the participants were interviewed for about 10-20 minutes. The questionnaire started with specific questions and was leading to an open discussion on the overall concept.

Observations and results

With the simple instructions given all users understood the basic principle of synchronized navigation and could perform the tests. In the first test (16 seconds cycle time) all users recognized the direction instruction given at the first instance. In 140 of 140 cases they went to the right direction. In the second test (8 seconds cycle time) in 137 of 140 cases participants went to the right direction at the first indication, in 3 cases at the second. When asked about the difference between the tests, 6 of 14 could not tell the difference. For those who recognized the difference in cycle time all preferred the shorter cycle time as they felt it makes navigation quicker even if they may miss an indication at the first instance.

In test 3 all participants put the phone into their trouser pockets, 12 in a front pocket and 2 in a back pocket. Several women in our study indicated that the usually carry their phone in their handbag, depending on what they wear and that notification by vibration would not work for them. Out of 280 instructions 276 direction indications were recognized at the first notification and 4 at the second.

When asked if they could imagine to use the system under time pressure 12 answered yes, 1 was not sure, and 1 said no. All stated that the speed to receive the directional cue is critical.

We asked participants where they could imagine deploying such navigation systems. The following application areas were stated: airports, railway stations, underground stations, inner cities and tourism, complex buildings (e.g. hospital, museum, and library), shopping malls, and trade fairs.

In the open interview participants reported in general that they found the navigation system straightforward and easy to use. Several people indicated that a personal navigation that is blended in the environment is appealing to them and that they did not want to focus on a personal screen while walking. They saw a great advantage in wearing the phone and receiving the direction cues unobtrusively.

The following potential problems were indicated. One user asked how can you discriminate between an incoming call and a navigational cue? In our prototype we used a distinct vibration patter for navigational cues, but we did not test calling participants while they performed the experiment. One user did not like the projection on the floor as she said it is not natural to look on the floor while walking, she would have preferred the projection on a wall. Two participants raised concerns if such projections may be distracting and unpleasant in certain environments.

RELATED WORK

There has been a lot of research in the area of pedestrian navigation systems in the last years. In [5] a typical outdoor navigation, system is presented. An early indoor navigation system is presented in [7]. In the area of augmented reality there has been research on combined indoor and outdoor navigation, e.g. [4]. Amongst those it was the REAL system described in [2] to be one of the first systems to combine a public and a personal device to provide indoor way instructions. In contrast to our approach, the devices were used sequentially and not in parallel and with a different goal in mind: users were first able to retrieve highly sophisticated 3D-navigation information from a large screen and then, while walking, able to access sketch-like information on a PDA. Other navigation systems rely exclusively on public screens, which are either smart doorplates, e.g. [1], or large information screens. In both cases privacy problems may arise, since private information is displayed in a public space. Furthermore it is difficult to design such systems so that they will work for multiple users.

Other mobile navigation concepts purely rely on tactile feedback to navigate users through spaces. GentleGuide [3] is a concept study that introduces haptic feedback through two vibrating devices that are worn at both wrists to provide indoor navigation. The vibrating devices silently indicate left or right turns to users at specific decision points. In ActiveBelt [6] the same principle with higher resolution has been implemented. ActiveBelt uses eight vibration devices attached to a waist belt to notify the user about directions to take. Both approaches share with our rotating compass system the advantages of hands-free operation. However GentleGuide and ActiveBelt require very precise information on the user's location, which makes their deployment in indoor environments either costly or limited. In contrast, our approach relies only on coarse information about the proximity of users to the public display. Cell-based localization techniques, e.g. based on Bluetooth, are therefore sufficient for a proper operation. Furthermore, as we only need a one bit personal display we are more flexible with regard to the devices we can use.

CONCLUSION

The work reported in this paper shows that the basic principle of the rotating compass navigation system is easily understandable by users. Our laboratory experiments indicate that users easily get the navigational cues on a personal device and can relate them to the information show on a public display. Overall in more than 97% of the cases people got the navigational cue at the first indication in 100% the cases they got it at the second indication.

Currently we are preparing a test in a public place. It is planned to have several different public displays that offer navigation information. Additionally we are investigating further options for one-bit personal displays that can be used for synchronized information presentation. In a further study we currently investigate the cognitive load for navigation with our system and look at how people perform in situations where they are distracted.

ACKNOWLEDGEMENTS

This work was performed in the context of the IST Project Simplicity funded by the EU and the DFG funded research group "embedded interaction".

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